MESO Transport and Dispersion Code

Presented at the BACIMO 2003 Conference
Session 3: Transport and Dispersion
Monterey, CA

Sept 9-11, 2003

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Sponsored by the **Naval Surface Warfare Center**, Dahlgren Division

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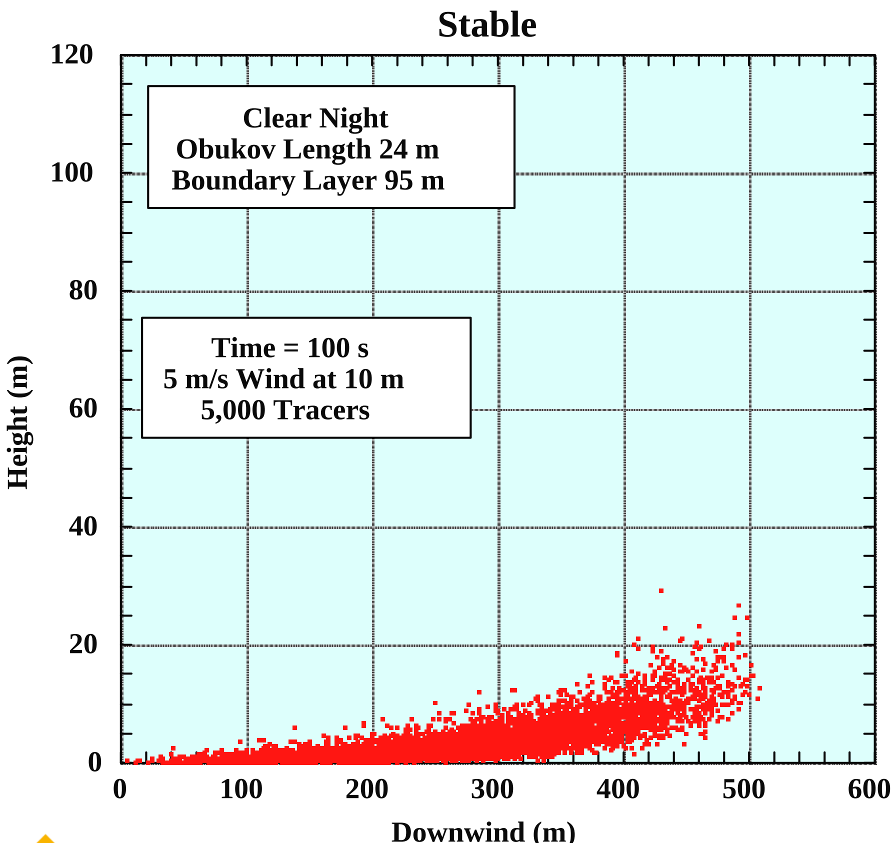
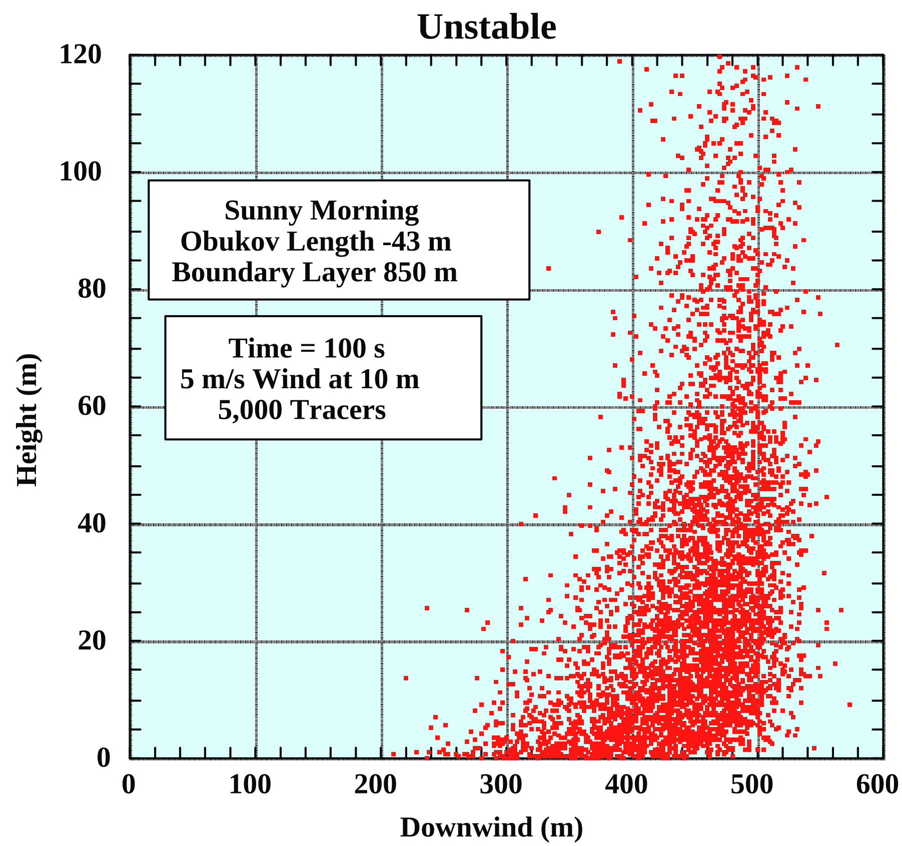
Introduction to MESO Transport and Dispersion Code

- Random-Walk Tracer Techniques
- 3D Time-Dependent Wind Fields
- Spatially-Varying Surface Characteristics
- Complex Terrain
- State-of-the-Art Meteorology
- Full Chem / Bio Capabilities





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~ 20,000 lines of code

MESO Stochastic Tracer Techniques

Clouds (Clusters)

Random Walk With Scale-Dependence

- Horizontal: Layer by layer
- Vertical: Whole cloud (but mixing length often limited by proximity to surface.)

Plumes

Horizontal: Langevin

Vertical:

- Stable: Random Walk (Diehl)
- Unstable: Stochastic technique of Franzese et al., 1999, Atmos. Environ. 33,2337-2345

<ins>Random Walk Technique</ins>: Diehl, et al. 1982, J. Applied Met., **21**, 69-83.

- Rigorously meets well-mixed condition (no drift)
- Numerically fast
- No grid required / good spatial resolution (1 to 40 m vertical)

<ins>Diffusivity</ins>: $\boldsymbol{K} = \mathrm{f}\,(\,\boldsymbol{\sigma_v, \lambda_m}\,)$
Statistical Theory With
Reduction for Droplet Inertia

<ins>Above PBL</ins>: CAT/Gravity Wave Models

Turbulence Parameterization

Function of: Height (z), Stability (L),
Friction Velocity (u_*),
Boundary Layer Height (h, z_i)

1) Near Surface, 2) Surface Layer,
3) Matching Layer, 4) Boundary Layer

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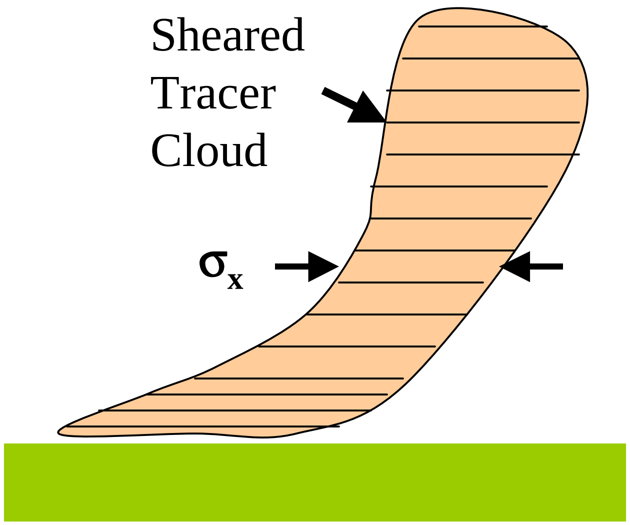
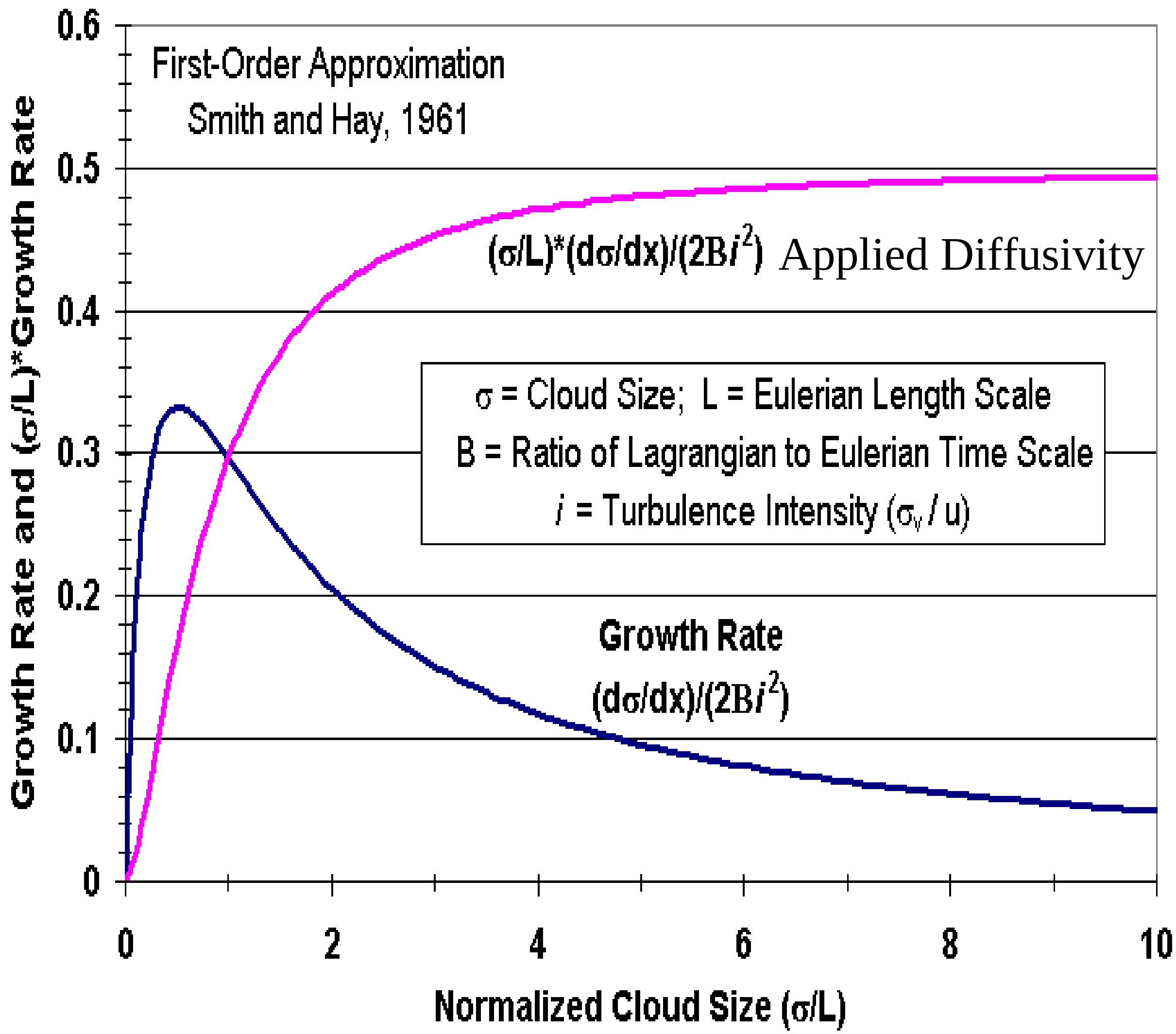
Cloud Growth Rate Integral

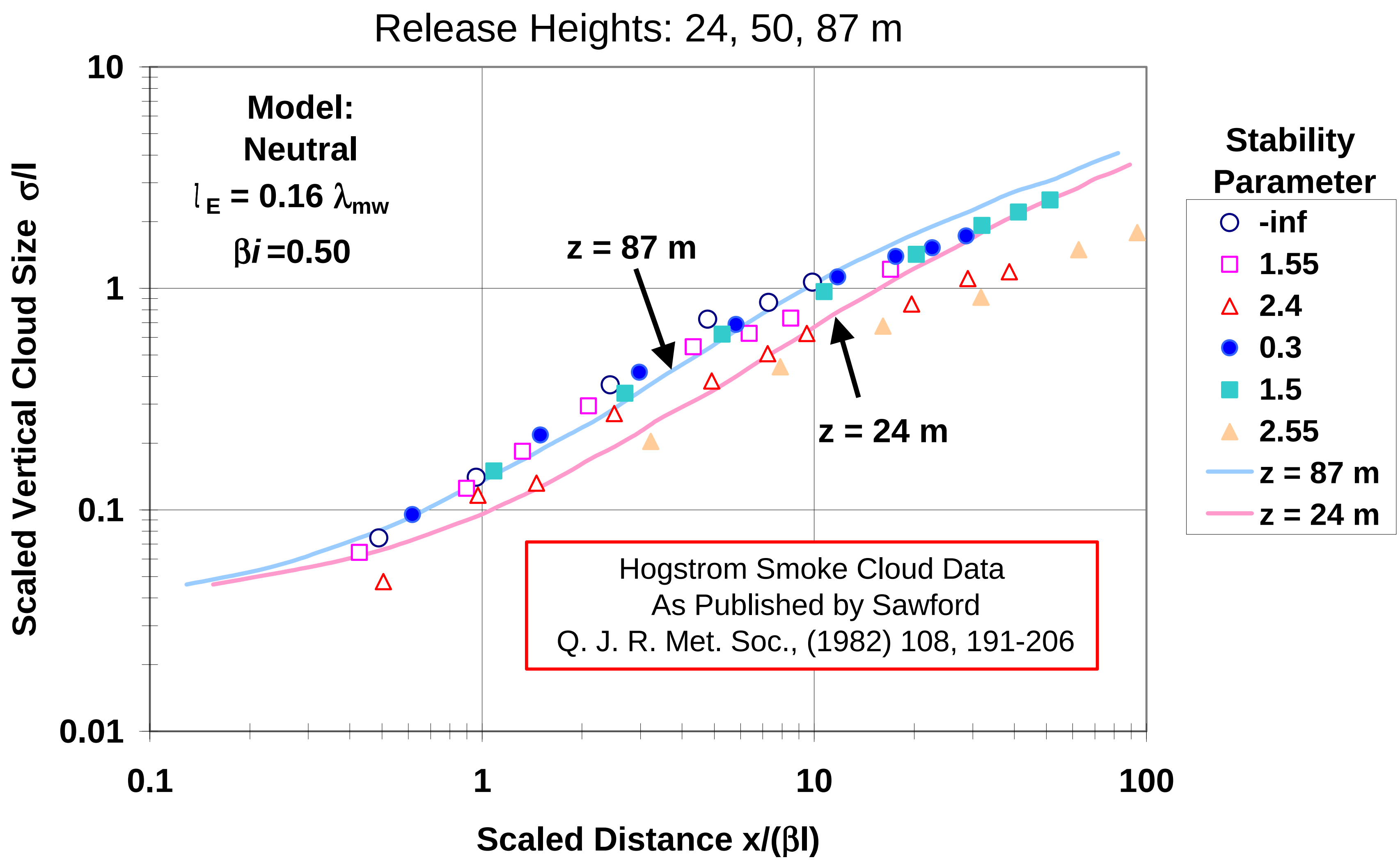
Horizontal Growth Handled By Layer



Growth Rate Curve Applied to Each Layer



Model Comparison To Measured Vertical Cloud Size



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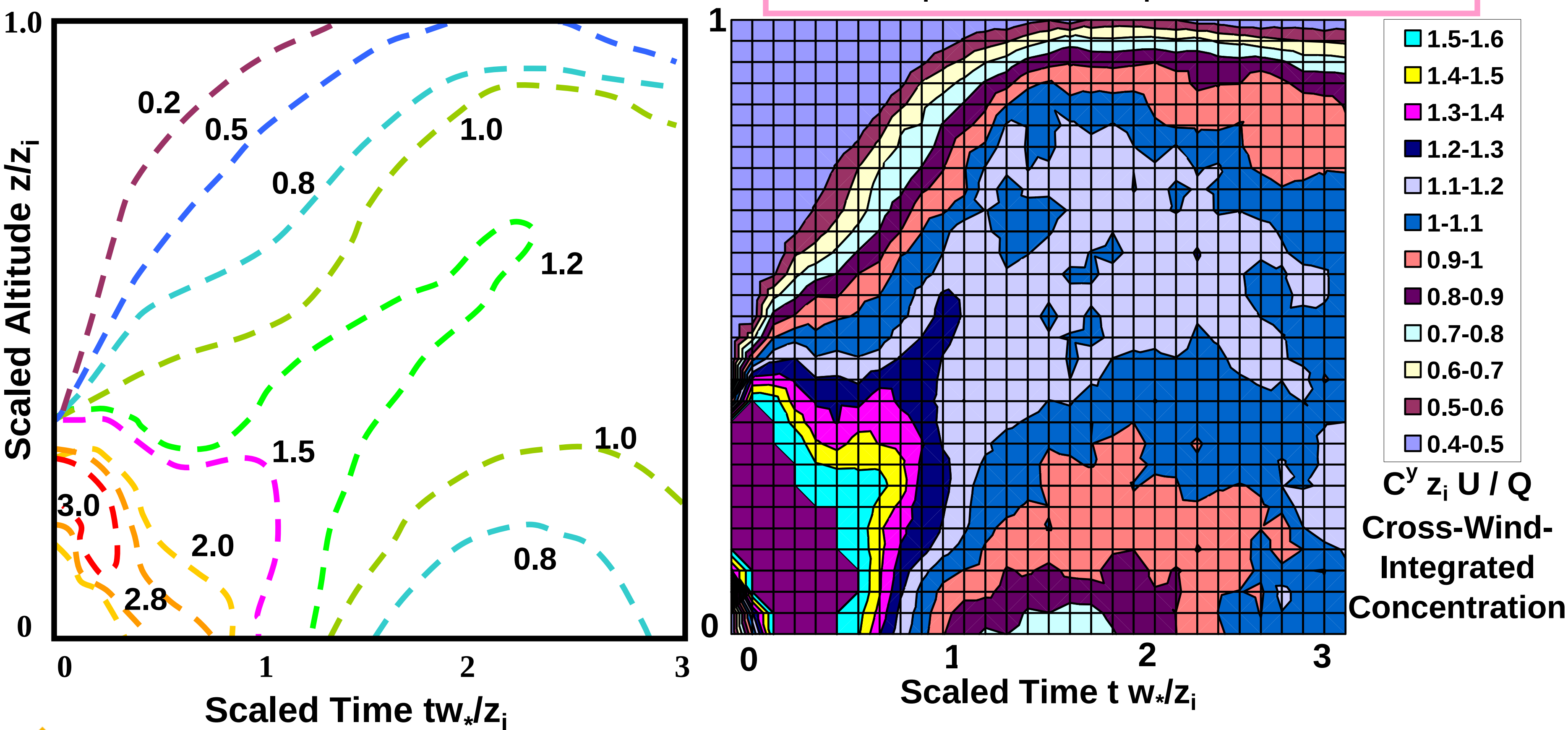
Comparison of Stochastic Plume Tracer Technique to Experiment

Water Tank Experiments of Willis and Deardorff

MESO: Stochastic Tracer Dispersion Technique of Franzese et al. (1999) With Improved Dissipation Term



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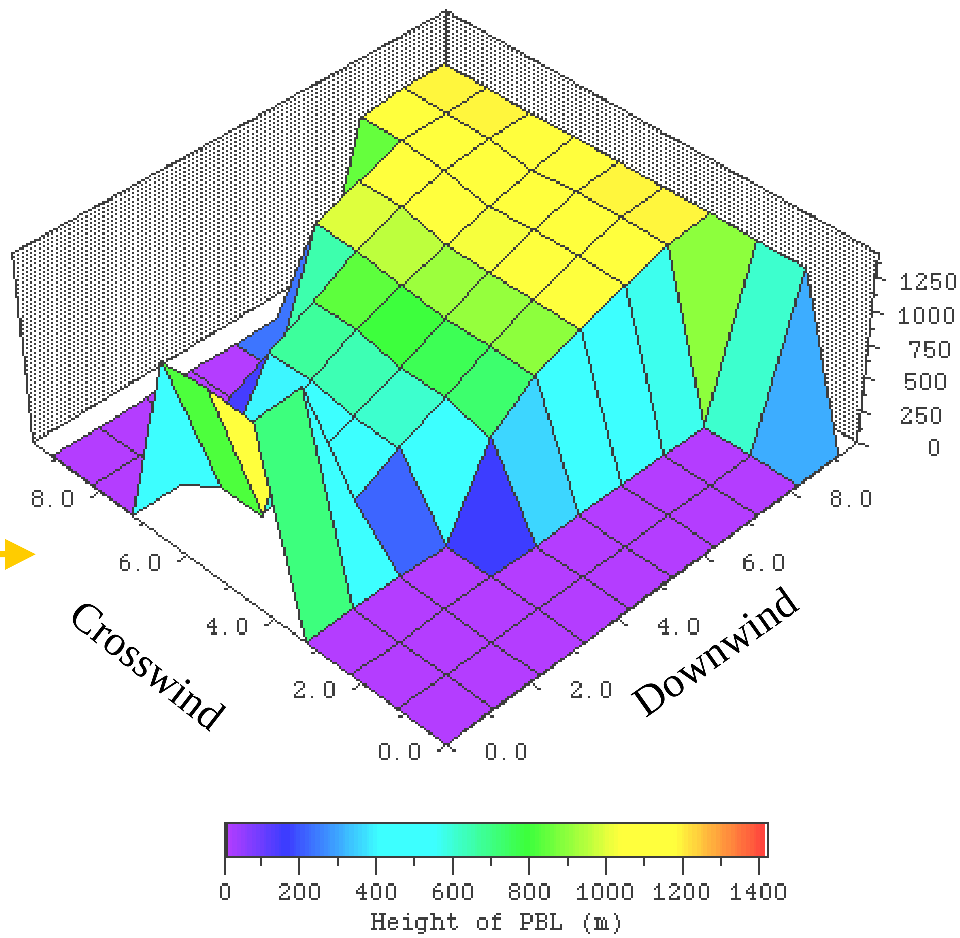
MESO Terrain/Surface Modeling

- 3D Time-Dependent Wind Fields Over Complex Terrain
- Terrain-Following Tracer Techniques to Prevent Artificial Deposition
- Each Ground Cell Treated Individually:
  - Surface Characteristics (albedo, surface roughness, moisture resistance, vegetation, etc.)
  - Input Meteorology (cloud cover, wind speed, RH, etc.)
  - Predicted Meteorology (u_*, L, w_*, z_i)

Advection: Predictor / Corrector Technique

Final Boundary Layer Height in Each Activated Ground Cell



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Night Time Heat Flux

Using Modified Method of van Ulden and Holtslag (1983)

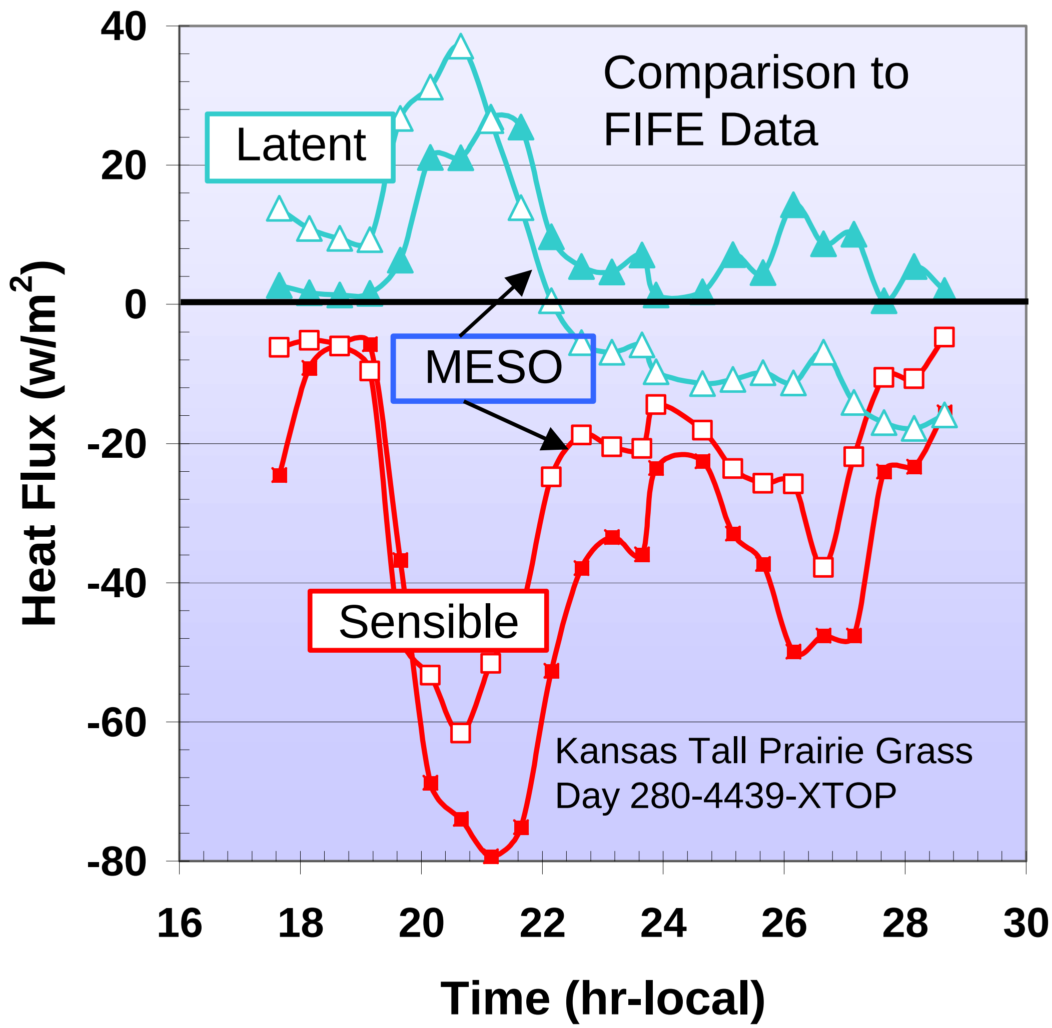
Starting Point: Sensible + Latent = Net Radiation - Ground

$$H + \lambda E = Q^* - G$$

IMPROVEMENTS

1) Added relative humidity terms to latent heat expression
2) Modified psychrometric constant γ using moisture resistance r_s.
3) More accurate expression for the net radiation.
4) Added improved expression for surface resistance.

Must iteratively solve complex nonlinear expression for u_* and L. (No multiple roots !)



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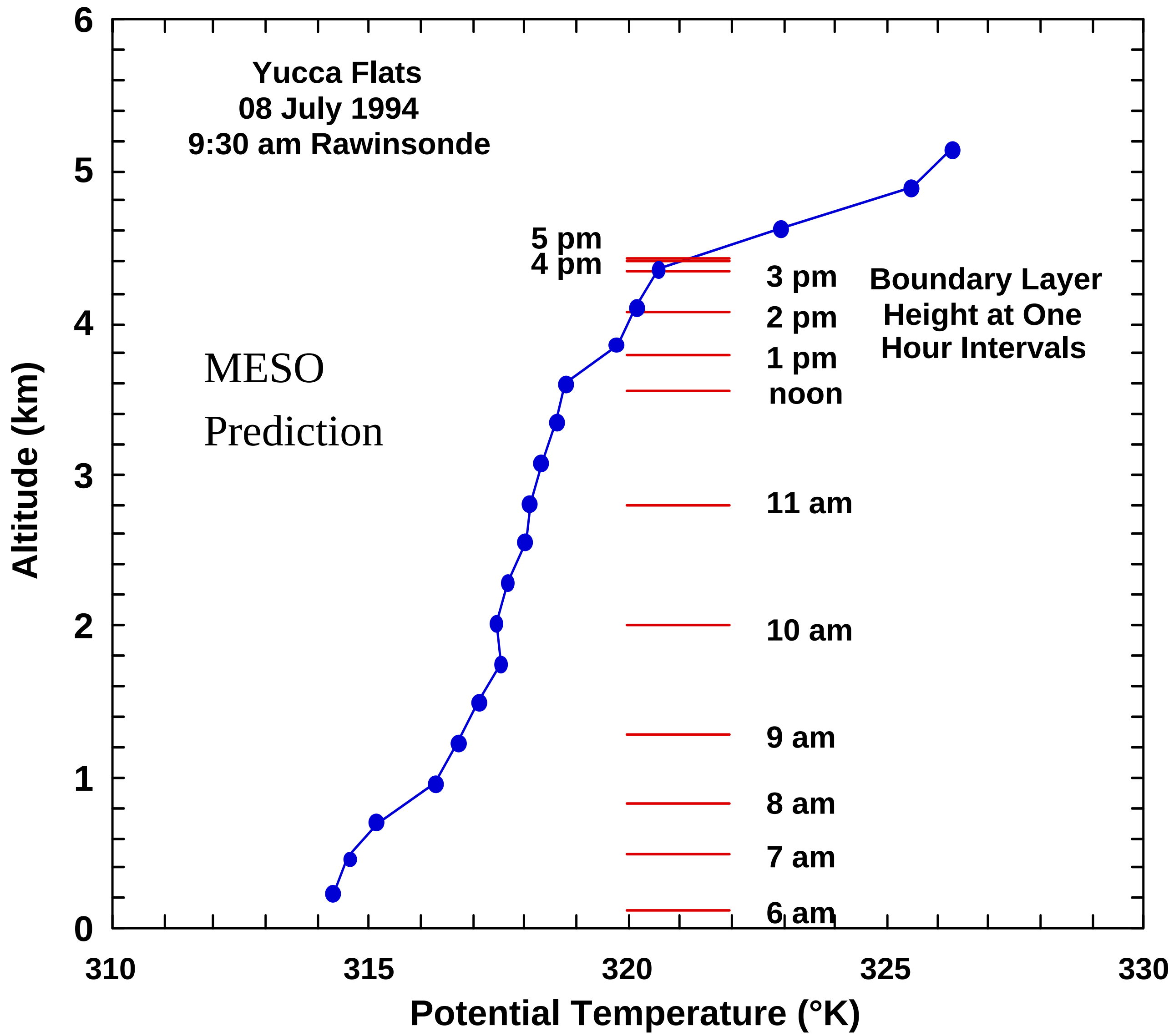
Predicted Growth of the Convective Boundary Layer

Based on Numerical Integration of Deardorff's (1974) Expression for dh/dt

Function of

- Current height h,
- Friction Velocity u_*,
- Coriolis Parameter f,
- Potential Temp Slope $d\theta/dz$,
- Monin-Obukhov Length L



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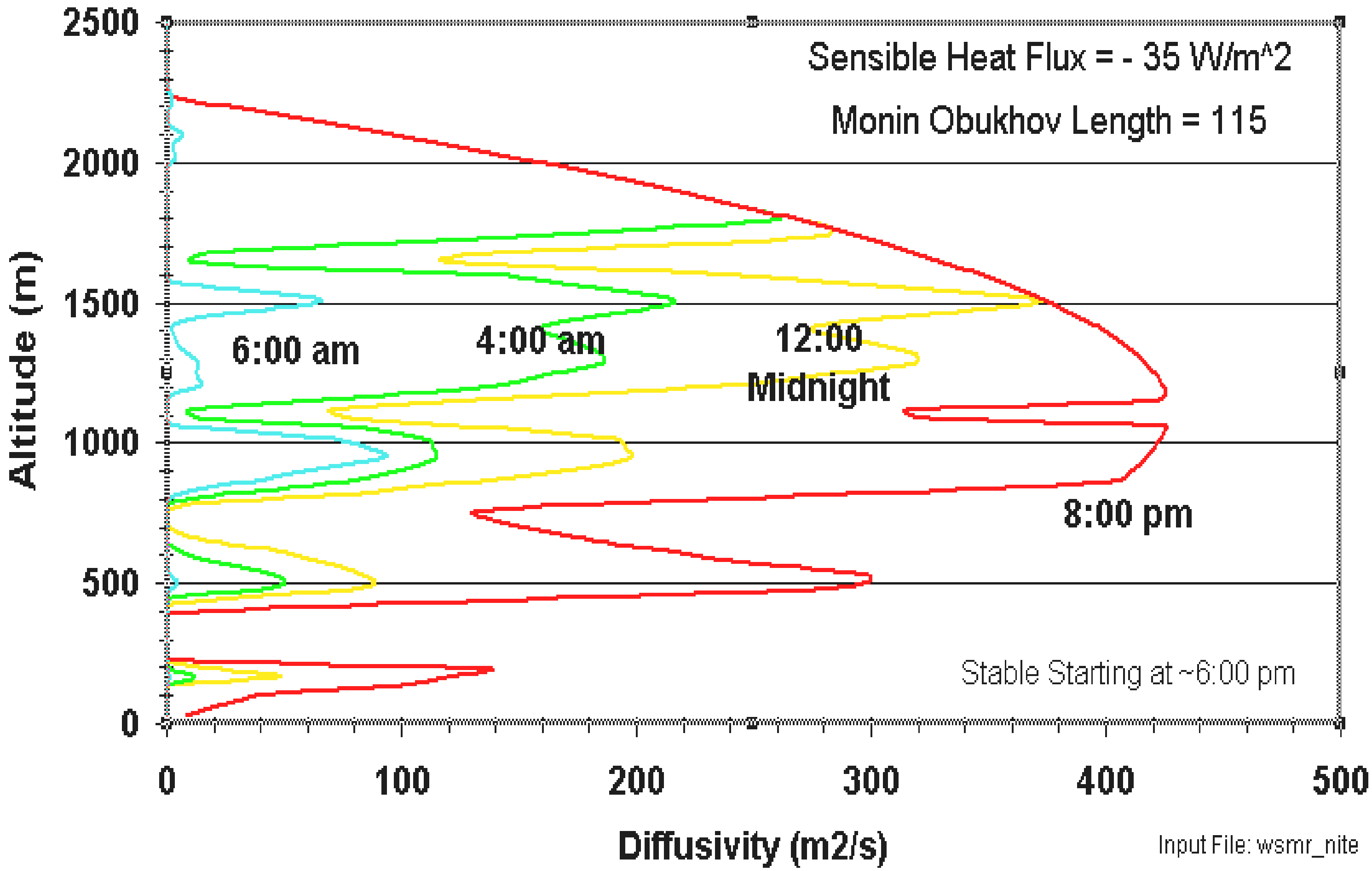
Predicted Breakup of the CBL Assuming Fixed Winds

- Functional form of pot temp θ(z) based on profiles found in the literature.
- Add sensible heat flux plus energy conservation to evolve the profile vs time.

Compute diffusivity profile from model based on Richardson number.



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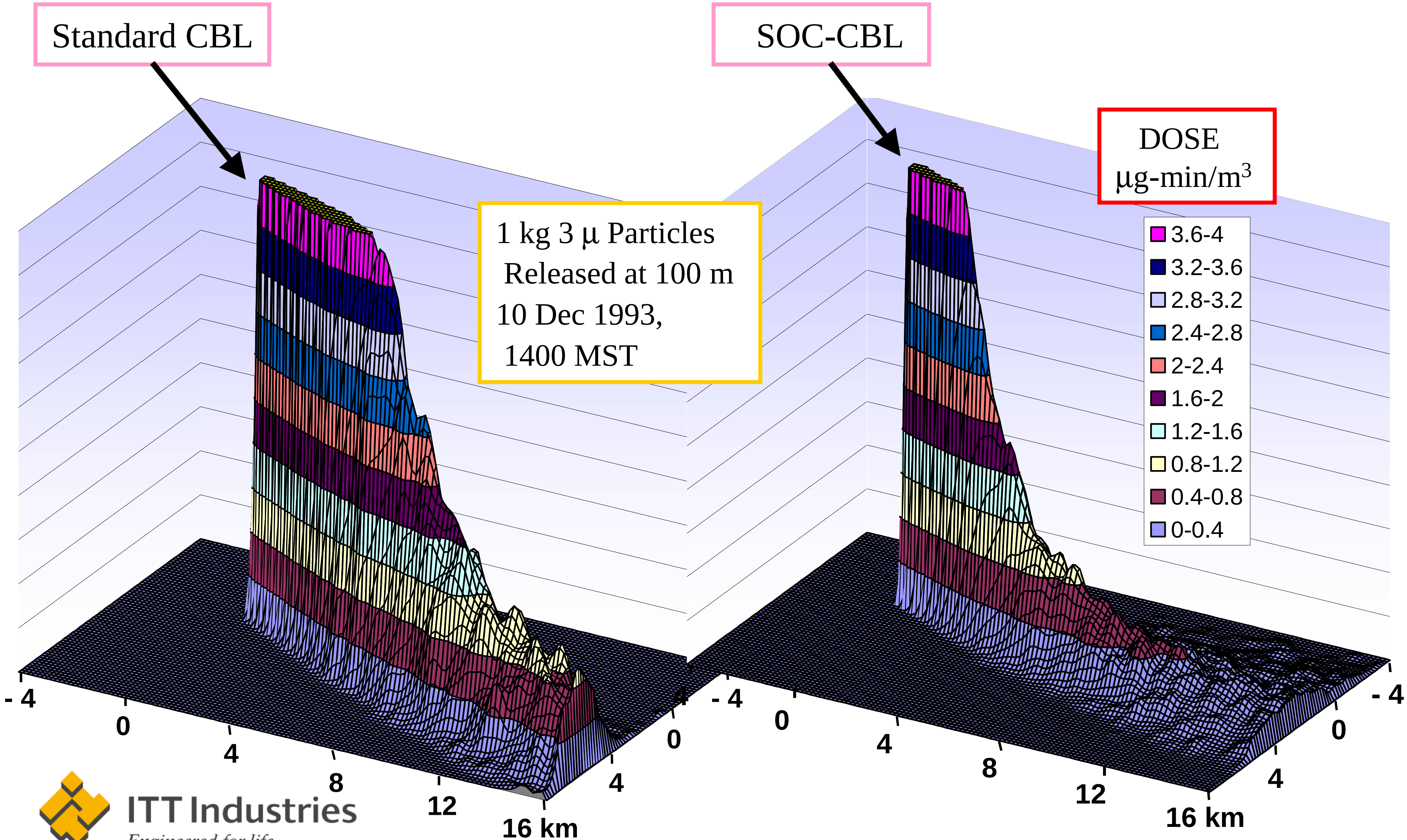
Dynamic Second-Order-Closure Model in MESO

- Preliminary Version of MESO Has Been Completed with Dynamic Second-Order Closure Capabilities.
- Numerically Advances the Prognostic Equation For Turbulent-Kinetic-Energy Using 1D Grid Through the Convective Boundary Layer (CBL).
- Important in High Shear Conditions and Uneven Terrain. Diffusivities Can Become Four Times Higher Than Seen in Standard Flat-Terrain Boundary Layers.
- Up-To-Date SOC Relations Are Used That Are In Agreement With Measurements and Large Eddy Simulations.
- The Model Uses a Turbulence Master Length Scale That Guarantees A Heat Flux Profile That Is In Agreement With Measured Profiles In Typical CBLs.

Effect of Dynamic 2nd Order Closure on Dispersion

For High Shear Winds at White Sand Missile Range



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Turbulent Deposition and Vegetation Filtration

MESO Contains Models To Handle:

- Turbulent Deposition of Particles to Rough Surfaces
- Vegetation Filtration

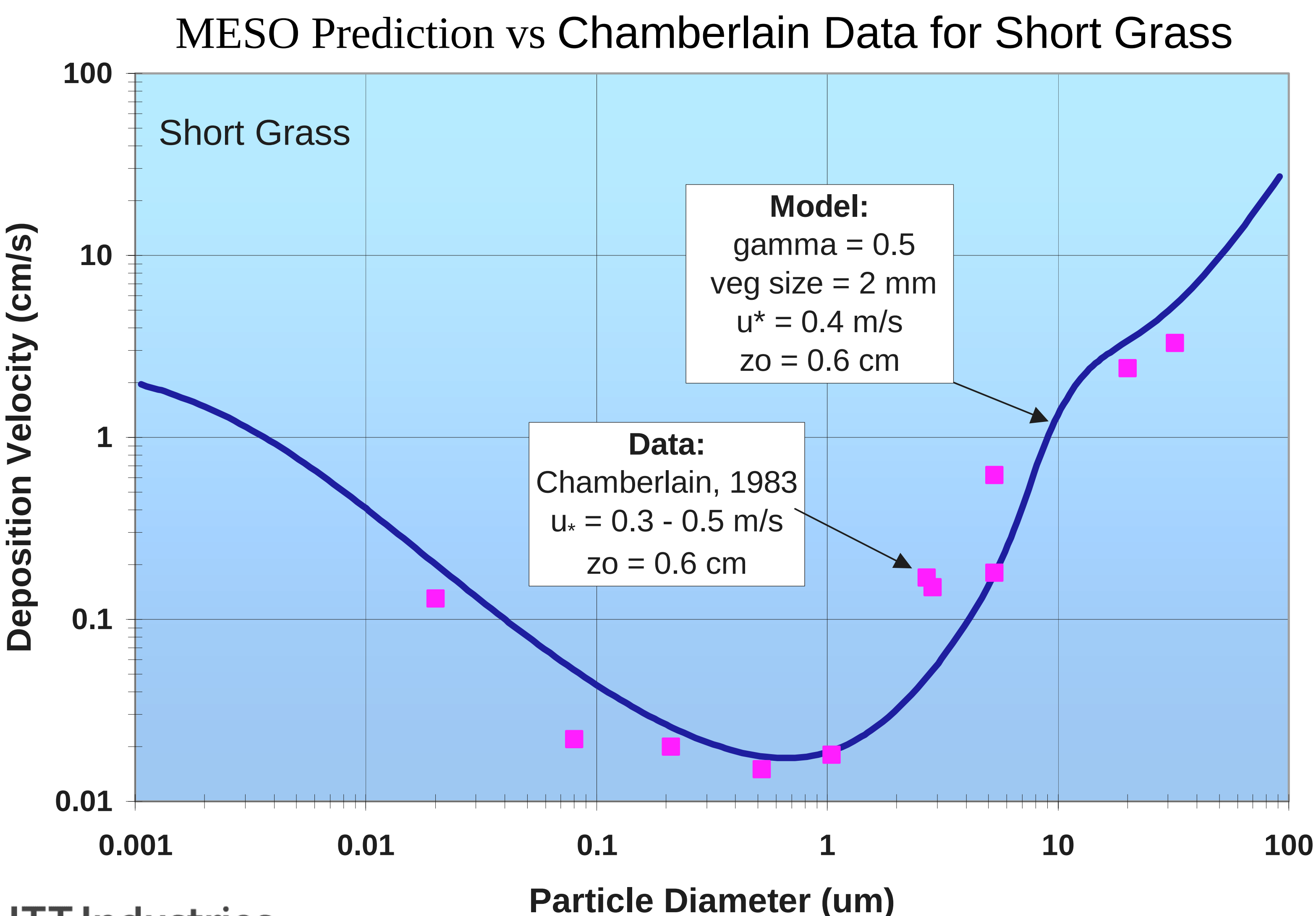
Both Are Strong Functions Of:

- Particle Size and Density
- Friction Velocity (wind speed)
- Atmospheric Stability (Obukhov length scale *L*)
- Surface Characteristics (surface roughness, characteristic size of the vegetation, vegetation density, wet/dry)

Models are user friendly:

- Select vegetation type
- Input estimate of density from 0. to 1.0.

Turbulent Deposition Model With Vegetation Filtration



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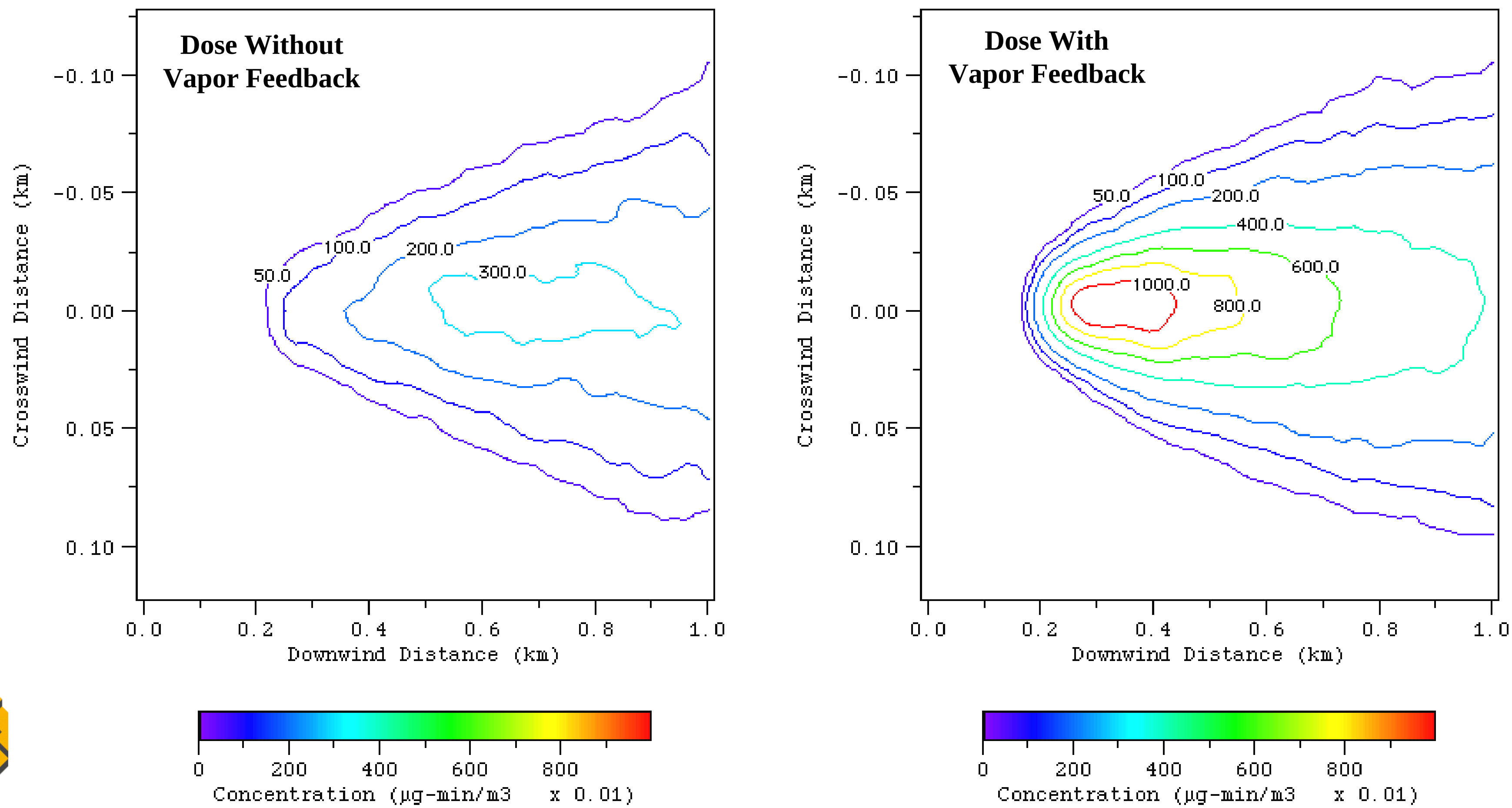
MESO Simulation With Droplet Evaporation

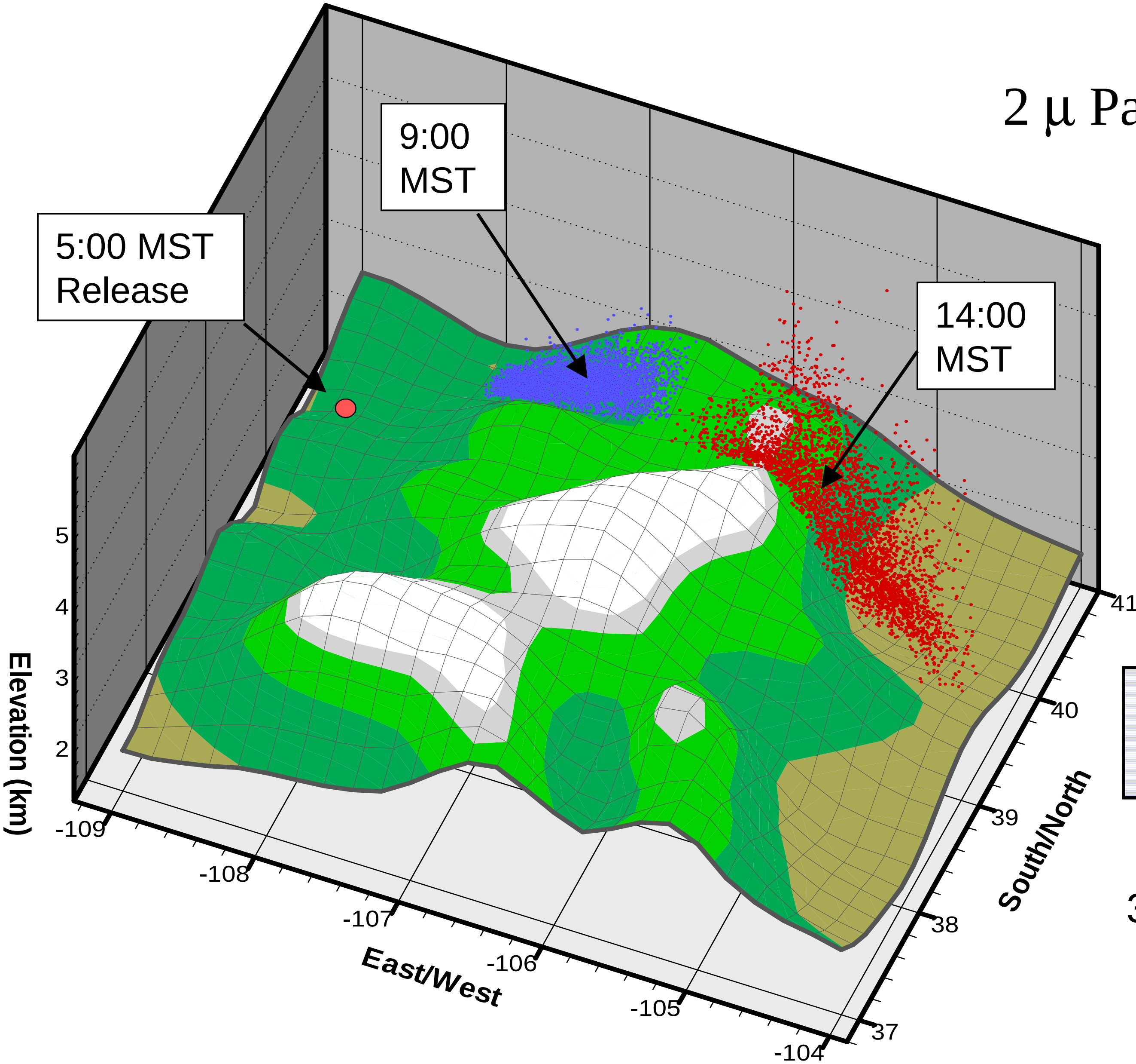
Source	Meteorology	
• 100 kg GB at Height = 50 m • 300 µm MMD (σ_g=1.1) • Initial Puff Size: σ = 2 m • 100,000 Droplet Tracers	• 5 m/s Wind Speed • Midlatitude Summer • 10:00 am Release • 0.7 Ground Cover	• 10 °C Surface Air Temperature • 0.1 m Surface Roughness • 0.3 Surface Albedo



Downloading Meteorology Forecasts to MESO

- **Code Developed to Download COAMPS Forecast Grid Data Using METCAST Scripting Language:**
  - 6 Hour Dumps at 0.2 Degree Resolution (~20 km cell size)
  - User can select longitude and latitude ranges to download.
  - Winds, Temperatures, Pressures, Cloud Cover, and Terrain (Relative Humidity, Surface Moisture, and Albedo can be easily added.)
  - Vertical winds generated by assuming quasi steady-state and using conservation of mass with dry-air thermodynamics.
  - Downloaded data is reformatted into MESO input met and terrain files.

MESO Simulation Using COAMPS Forecast Download

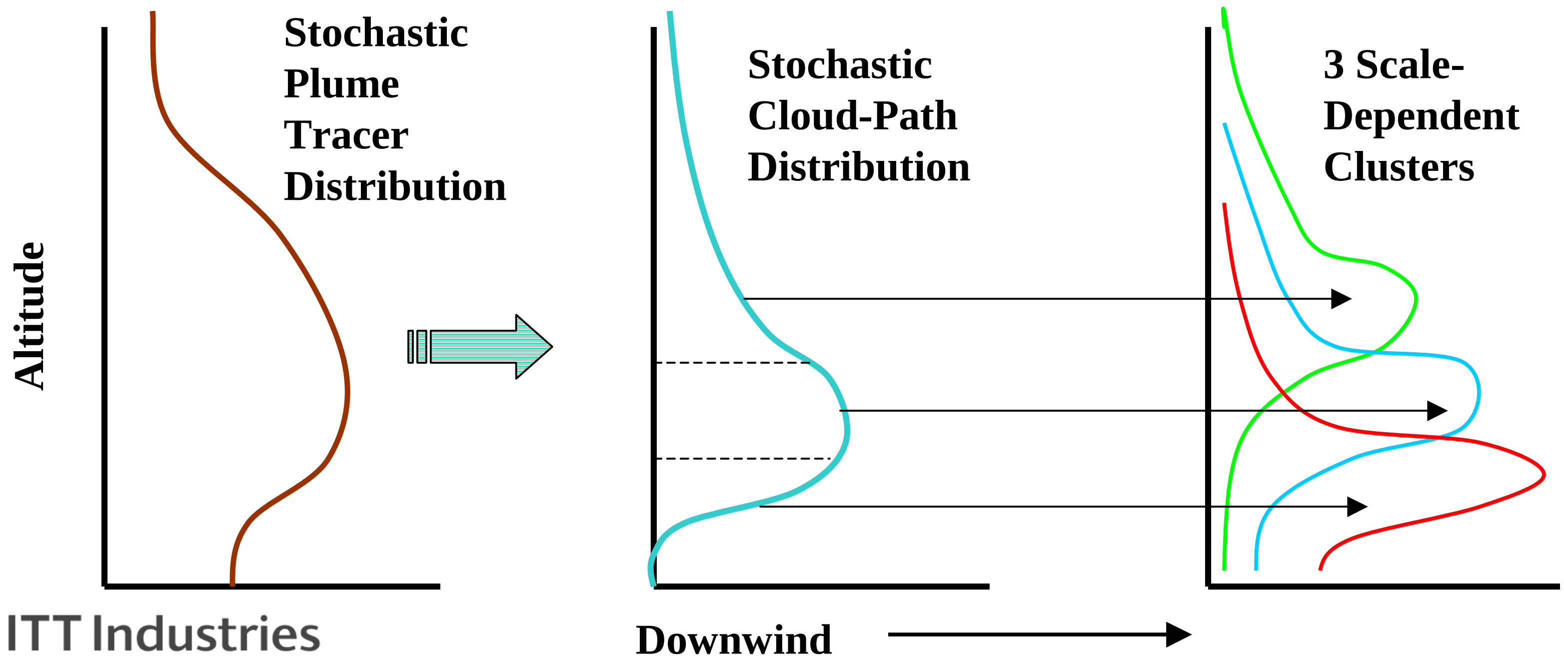


Western ¾ of Colorado

31 Dec 2002

Dose/Deposition Variance Technique

1. Using stochastic tracer techniques, model three scale-dependent “cloud” clusters and one plume cluster. (All three follow the average wind direction.)
2. Each cycle, convert plume tracers to path tracers.
3. Divide path tracer distribution into three altitude groups: low, medium, high
4. Force three “true” cloud clusters to track at height of three path groups.
5. Each cycle, save deposition and concentration near the ground (for dose).
6. Accumulate Dose/Dep from 3 clouds over many cloud paths.



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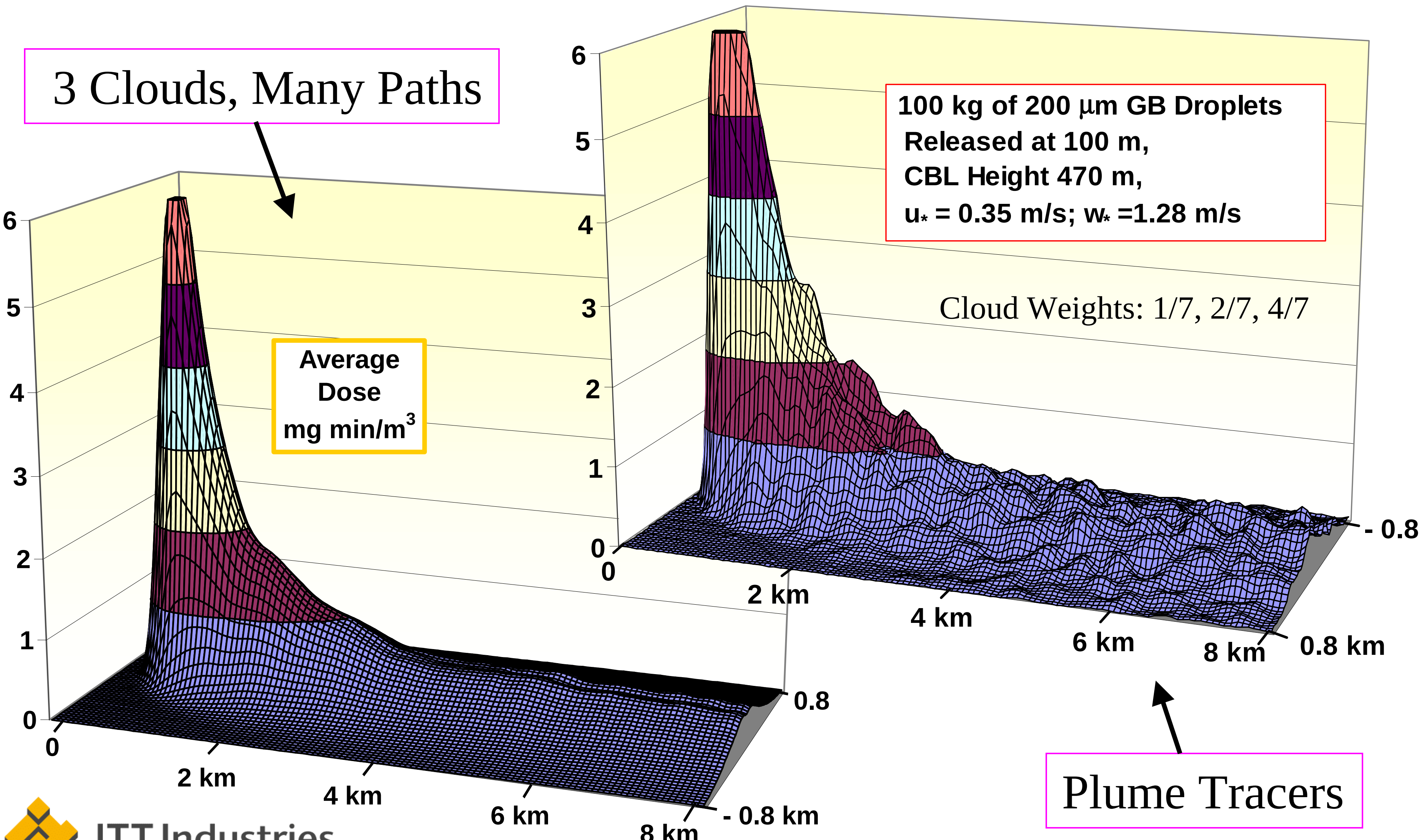
Comparison Between Average Dose From Plume Tracers and 3-Cloud Many-Paths Method: Code Verification



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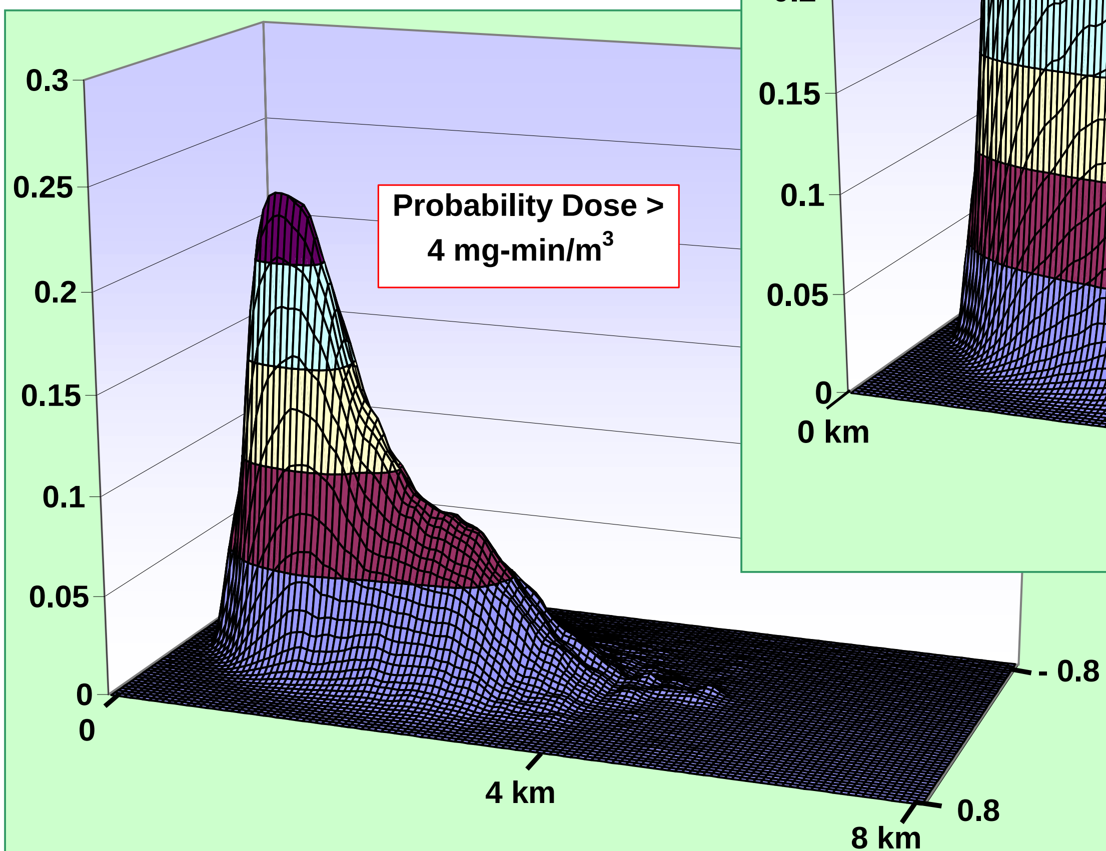
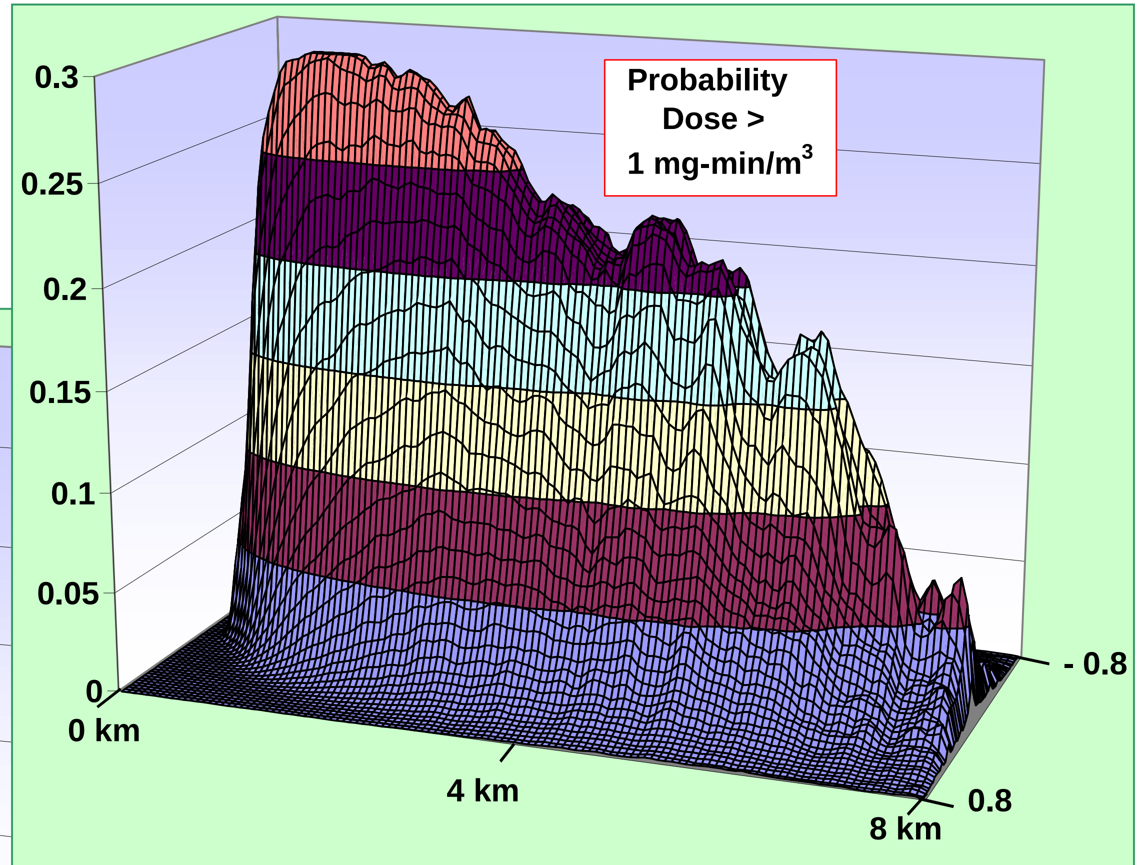
Conditional Probability of Dose Greater Than Given Value

100 kg of 200 µm GB Droplets

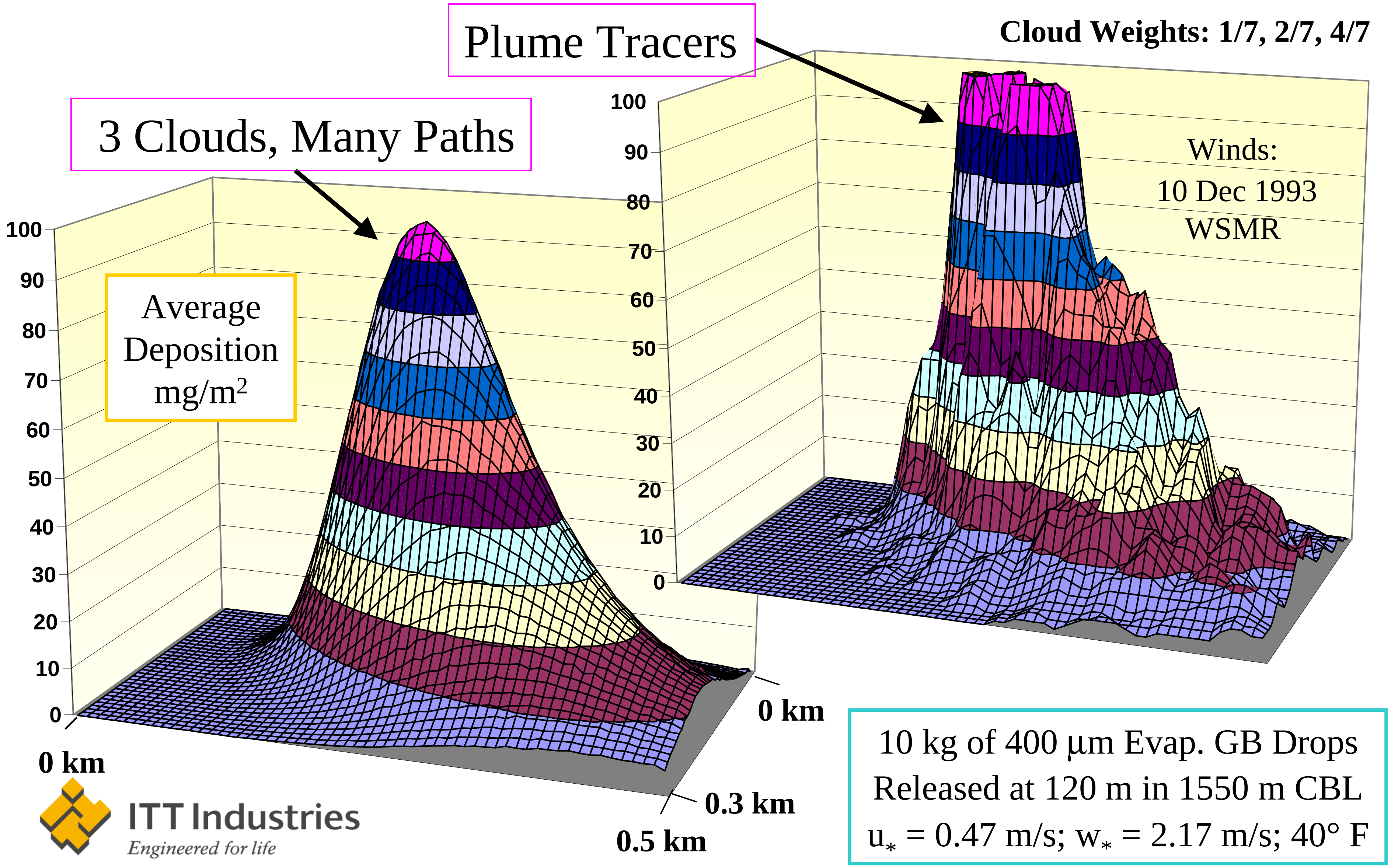
Released at 100 m in 470 m CBL

$w_* = 1.28$ m/s, $u_* = .35$ m/s





Comparison Between Average Droplet Deposition From Plume Tracers and 3-Cloud Many-Paths Method: Code Verification



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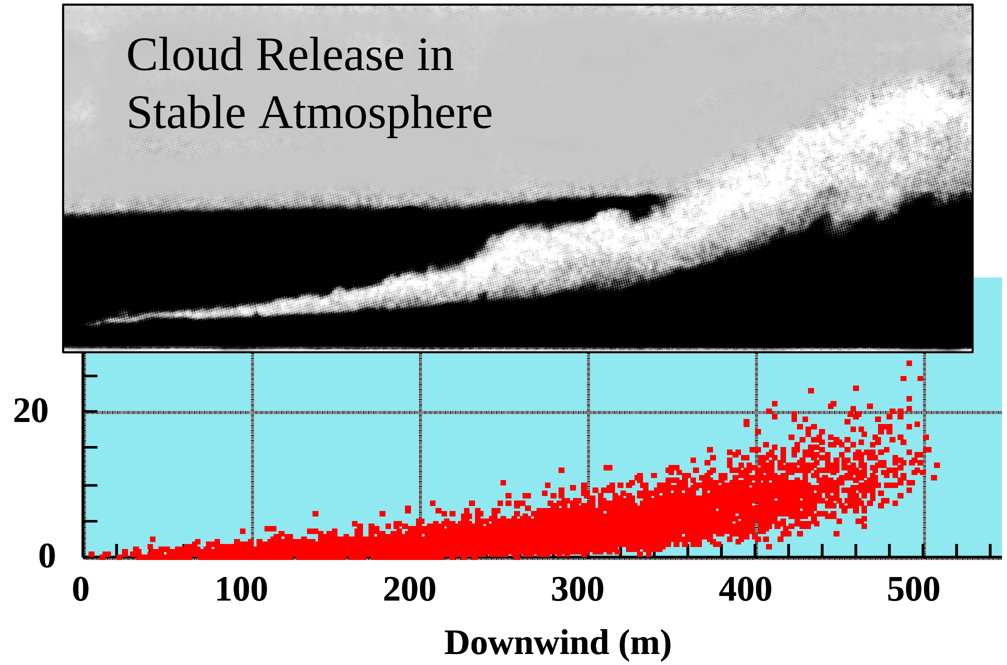
MESO Validation

- High Stack Emissions (old)
- Crystal Mist Test Data (High Altitude and High PBL)
- Dugway Test Data (Surface Deposition)
- Standard Surface Releases
  - Rough Cut with Prairie Grass data
  - Correct vertical and lateral spread with distance
- Pea Sooper (1.0 and 1.5 mm Beads)

Thorough Validation Effort Currently Underway By NSWC



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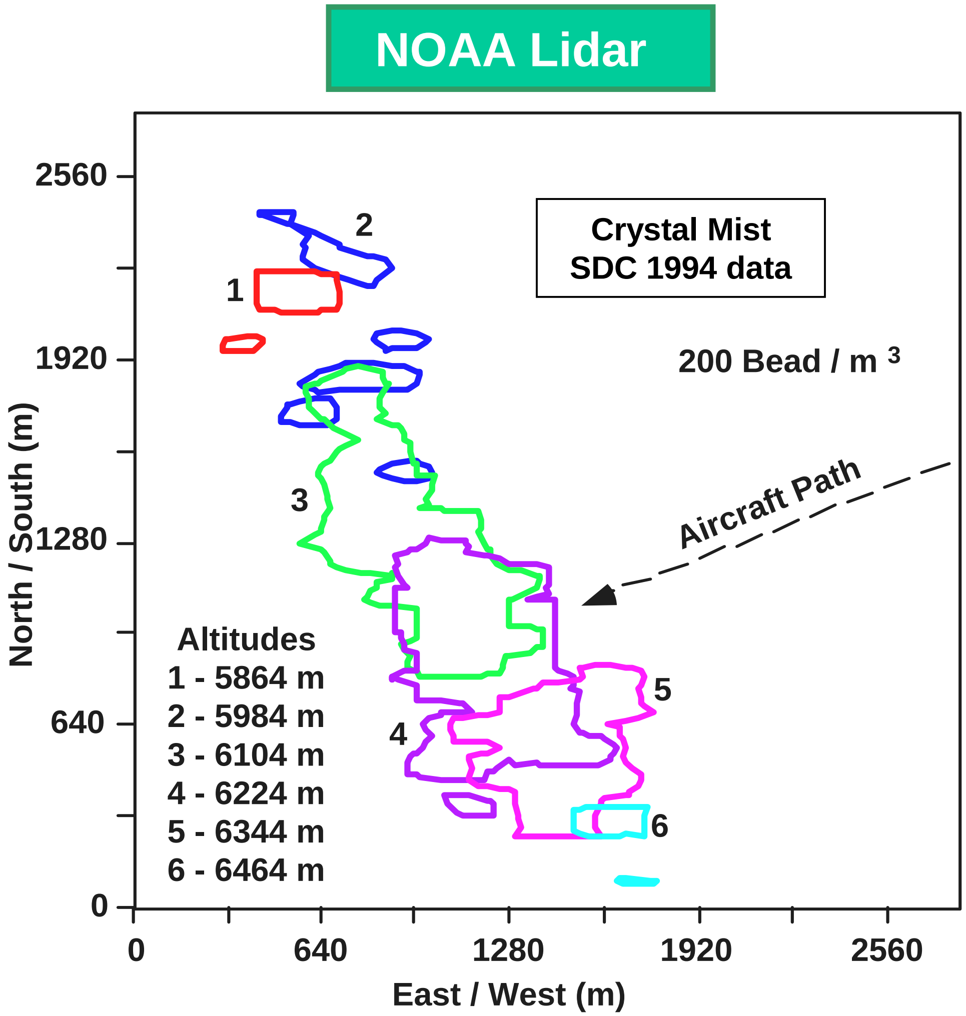
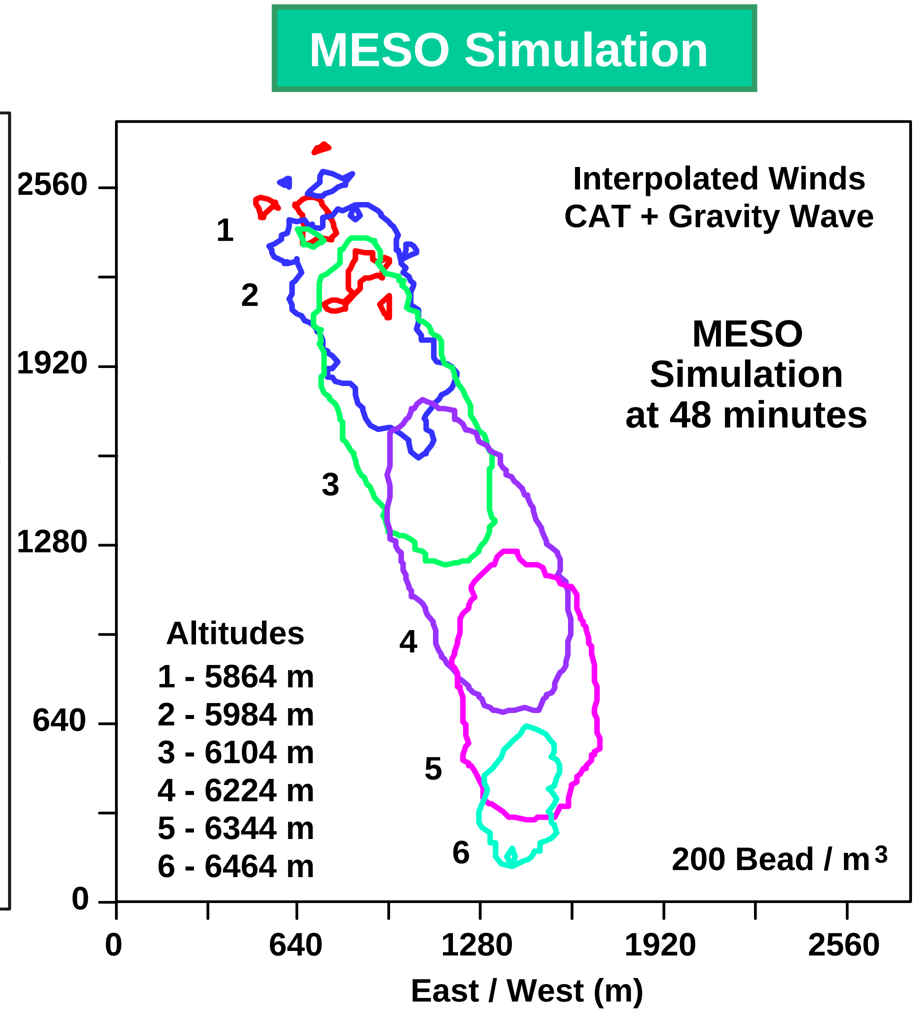
Comparison Between NOAA Lidar and MESO





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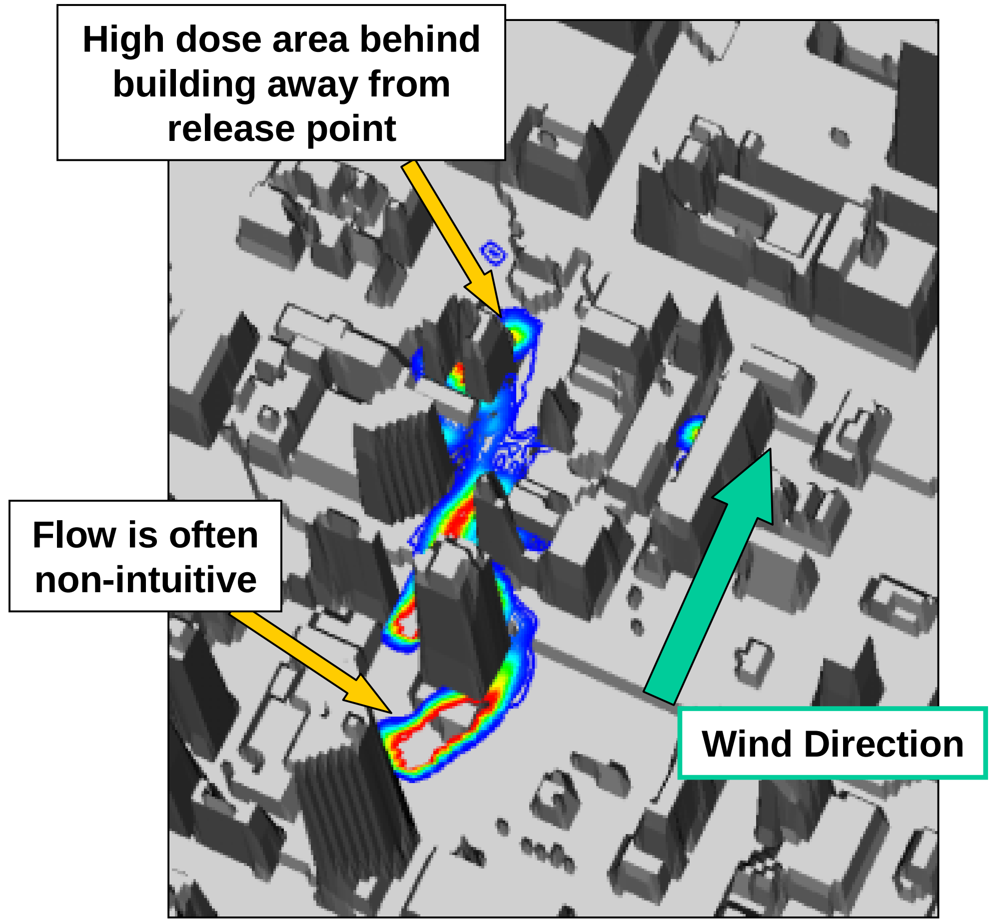
48 min after release

Nevada Test Site
13 July 1994

MESO Urban Modeling Using RUSTIC CFD Predictions

MESO is being modified for urban modeling with RUSTIC:

- Modified to accept RUSTIC (and ADVEDS) wind field and turbulent kinetic energy (TKE) data
- To handle abrupt objects with detached flow
- Modified with an urban plotting capability
  - Dose and deposition plots
  - Concentration plots
  - Streamlines and random-walk particle paths



Dose from two release points (Note high dose behind building at far end where eddies form and particles circulate.)

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Code Status

- Heading into code verification/validation stage by Naval Surface Warfare Center
- A few sections of the code need additional time to mature and to make more "user friendly:"
    - Forecast Downloads (maturing rapidly)
    - Dynamic Second-Order Closure Model (in the code but in a research form)
    - Dose / Deposition Variance and Conditional Probability. (Additional code work still needed, but should be complete in FY03.)
    - Urban Modeling With CFD Winds. Improvements still needed in:

      1) CFD turbulence modeling,

      2) Atmospheric stability modeling, and

      3) Handling of upwind atmospheric turbulence.

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